SENTINEL-3 POD PRODUCTS PERFORMANCE

COPERNICUS SENTINEL-1, -2 AND -3 PRECISE ORBIT DETERMINATION SERVICE (SENTINELSPOD)

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DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	29/10/2013	10	First version of the document
1.1	20/12/2013	11	Update for S-2 and S-3 SDR close-out • Update of applicable documents • Correct purpose of document (GMESPOD-S2-SDR-28). Section 1.1 • Correction of performance of S-3 platform data files (GMESPOD-S3-SDR-35, GMESPOD-S3-SDR-36) • Addition of reference to the products handbook and link to the processing baseline (GMESPOD-S3-SDR-112)
1.2	13/02/2015	10	Update for S-3 ORR: • Update of applicable documents • Correct typos
1.3	27/03/2015	10	Update for S-3 ORR close out: • Correct typo into section 2.2 (RID GMESPOD-S3-ORR-40)
1.4	17/05/2017	12	Update after RSR#7: • Applicable documents updated in section 1.4.1 • Reference documents added in section 1.4.2 • Results of up-to-date RSRs included in table 3-2
1.5	18/12/2019	27	Changes: • To include list of acronyms (section 1.3) • To update applicable and reference documents (section 1.4.1) • To include new values up to September 2019 (section 3) • To include plots with the evolutions (section 3.5)
1.6	18/05/2020	24	Update after RSR#16: • To update applicable and reference documents (section 1.4.1) • To include the new values of the RSR#16 (section 3.4) • To update the plots with the evolutions (section 3.5)
1.7	04/08/2020	25	Update after RSR#17: • To update applicable and reference documents (section 1.4.1) • To include the new values of the RSR#17 (section 3.5) • To update the plots with the evolutions (section 3.6)

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1. INTRODUCTION

1.1. PURPOSE

This document presents the Sentinel-3 POD Products Performance. It describes the performance of each of the POD products generated for Sentinel-3 as compared to the POD requirements (position accuracy, coverage, timeliness, latency). The Cal/Val plan of the Sentinel-3 mission [AD.2] presents completely the calibration and validation tasks aimed at characterising the accuracy of the Sentinel-3 POD products. As part of the Cal/Val tasks, different reports are generated that justify the values presented in this document. Morevover, the Sentinel-3 POD products Quality Control Plan [AD.3] also provides information about metrics computed routinely related to the accuracy of the Sentinel-3 POD products.

This document is intended as a living document that describes the accuracy of a set of POD products for Sentinel-3 generated with a given POD system version. Thus, different accuracies are described for each processing baseline (POD system version and input data). Additional information is added to this document when a new processing baseline is used.

1.2. SCOPE

This document is a deliverable by GMV in the frame of the Provision of the Precise Orbit Determination Service for the Sentinel-3 mission project.

1.3. DEFINITIONS AND ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 1-1: Acronyms

Acronym	Definition	Acronym	Definition
AD	Applicable Document	MWR	Micro-Wave Radiometer
AIUB	Astronomical Institute University of Bern	NAPEOS	NAvigation Package for Earth Orbiting Satellites
CNES	Centre National d'Études Spatiales	NRT	Near Real Time
CPOD	Copernicus POD	NTC	Non Time Critical
DIL	Document Item List	ORR	Operational Readiness Review
DLR	Deutsche Zentrum für Luft- und Raumfahrt	PDGS	Payload Data Ground Segment
ERS	European Remote Sensing	POD	Precise Orbit Determination
ESA	European Space Agency	POE	Precise Orbit Ephemeris
ESOC	European Space Operation Centre	RD	Reference Document
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites	RID	Review Item Discrepancy
GFZ	Geo Forschungs Zentrum	RMS	Root Mean Square
GHOST	GPS High Precision Orbit Determination Software Tools	ROE	Rapid Orbit Ephemerides
GINS	Géodesie par Intégrations Numériques Simultanées	RSR	POD Regular Service Review
GIPSY-OASIS	GNSS Inferred Positioning SYstem and Orbit Analysis Simulation Software	SAR	Synthetic Aperture Radar
GMES	Global Monitoring for Environment and Security	SDR	Software Defined Radio
GNSS	Global Navigation Satellite System	SPOD	Sentinels POD
GRG	Groupe de Recherche de Géodésie Spatiale	SPOT	Satellite pour l'Observation de la Terre
ID	Identifier	STC	Short Time Critical
IPF	Instrument Processing Facility	SW	Software

Acronym	Definition	Acronym	Definition
JPL	Jet Propulsion Laboratory	TD	Technical Documentation
LND	Land centre	TN	Technical Note
MAR	Marine centre	TUD	Technische Universiteit Delft
MOE	Medium Orbit Ephemeris	TUM	Technische Universität München
MSI	Multi-Spectral Instrument	USO	Ultra Stable Oscillator

1.4. APPLICABLE AND REFERENCE DOCUMENTS

1.4.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 1-2: Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	Sentinels POD Service File Format Specification	GMES-GSEG-EOPG-FS-10-0075	1.24	19/11/2019
[AD.2]	Sentinel-3 POD Cal-Val Plan	GMV-GMESPOD-TN-0008	1.3	27/03/2015
[AD.3]	Sentinels POD Service S-3 Products Quality Control Plan	GMV-GMESPOD-TN-0005	1.3	27/03/2015
[AD.4]	Sentinels POD Product Handbook	GMV-GMESPOD-TN-0009	1.14	18/05/2020

1.4.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, extend or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 1-3: Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	Copernicus POD Regular Service Review Feb-May 2016	GMV-GMESPOD-RSR-0005	1.0	01/07/2016
[RD.2]	Copernicus POD Regular Service Review Jun-Sep 2016	GMV-GMESPOD-RSR-0006	1.1	01/07/2016
[RD.3]	Copernicus POD Regular Service Review Oct 2016-Jan 2017	GMV-GMESPOD-RSR-0007	1.0	03/03/2017
[RD.4]	Copernicus POD Regular Service Review Feb-May 2017	GMV-GMESPOD-RSR-0008	1.1	28/07/2017
[RD.5]	Copernicus POD Regular Service Review Jun-Sep 2017	GMV-GMESPOD-RSR-0009	1.0	30/10/2017
[RD.6]	Copernicus POD Regular Service Review Oct 2017 - Jan 2018	GMV-GMESPOD-RSR-0010	1.1	07/03/2018
[RD.7]	Copernicus POD Regular Service Review Feb-May 2018	GMV-GMESPOD-RSR-0011	1.1	31/07/2018
[RD.8]	Copernicus POD Regular Service Review Jun-Sep 2018	GMV-GMESPOD-RSR-0012	1.0	31/10/2018
[RD.9]	Copernicus POD Regular Service Review Oct 2018 - Jan 2019	GMV-GMESPOD-RSR-0013	1.0	01/03/2019
[RD.10]	Copernicus POD Regular Service Review Feb-May 2019	GMV-GMESPOD-RSR-0014	1.1	19/07/2019
[RD.11]	Copernicus POD Regular Service Review Jun-Sep 2019	GMV-GMESPOD-RSR-0015	1.0	31/10/2019
[RD.12]	Copernicus POD Regular Service Review Oct 2019 - Jan 2020	GMV-GMESPOD-RSR-0016	1.0	04/03/2020
[RD.13]	Copernicus POD Regular Service Review Feb-May 2020	GMV-GMESPOD-RSR-0017	1.1	04/08/2020

2. COPERNICUS POD SERVICE CONTEXT

2.1. COPERNICUS POD SERVICE OVERVIEW

The **Copernicus program** (formerly known as GMES, Global Monitoring for Environment and Security) is a joint initiative of the European Commission and the European Space Agency (ESA), designed to support a sustainable European information network by monitoring, recording and analysing environmental data and events around the globe. The Copernicus program will consist of five different families of satellites.

The first family is **Sentinel-1**, which consists of two satellites with imaging C-band radars. This family continues the C-band SAR data gathered by ERS and Envisat missions. The second family is **Sentinel-2**, which consists of two satellites with optical sensors. This family continues providing the products delivered by Landsat and SPOT missions. The main instrument of the Sentinel-2 satellites is the Multi-Spectral Instrument (MSI), which operates from the visible to the shortwave infrared. The last family of the Copernicus program taken into consideration here is the **Sentinel-3**, which consists of two satellites with several sensors to continue the products of Envisat and ERS missions. Following are the products to be provided by the Sentinel-3 mission: surface colour products, surface temperature products, land vegetation products, surface topography products, which are derived from the combination of data produced by the Radar Altimeter, MWR and GNSS receiver.

The **Copernicus POD (CPOD) Service** is part of the **PDGS Ground Segment** of the Sentinels missions and is in charge of the generation of precise orbital products and auxiliary data files for their use as part of the processing chains of the respective Sentinel PDGS. The Copernicus POD Service is a service **developed and operated by GMV** with a system running on a cloud environment and providing products for the Sentinel missions with various timeliness: near real-time (NRT), short-time critical (STC), non-time critical (NTC) and reprocessing. On the other hand, the **S-3 POD IPF** is a software developed as part of the Copernicus POD Service that runs at the S-3 PDGS generating near-real time orbits for the Sentinel-3 mission.

2.2. SENTINEL-3 CPOD SERVICE PRODUCTS PERFORMANCE OVERVIEW

The main POD products generated by the CPOD Service associated to the Sentinel-3 mission are: the NRT restituted orbit file and NRT platform data file generated by the S3 POD IPF, and the MOE and POE orbit files and the Preliminary and Precise Platform Data files generated by the Copernicus POD Service Centre. The following performance requirements are defined for each of these products [AD.1]:

- **NRT Restituted Orbit File**:
  - The position accuracy threshold is 10 cm radial 1-sigma RMS with a target of 8 cm.
  - The file is generated within 30 minutes from the reception of GNSS input data.
  - The file coverage is equal to the input file coverage (GNSS data) plus at least 5 orbital state vectors (configurable) before and after the period of the GNSS data in input. One file is generated for each input received and contains orbital state vectors at fixed time steps of 10 seconds.
- **MOE Orbit File**:
  - The position accuracy threshold is 4 cm radial 1-sigma RMS with a target of 3 cm.
  - The file is generated per day with a latency of 36 hours.
  - The file coverage is 26 hours with orbital state vectors from d-3 at 22 h to d-2 at 24 h for the product corresponding to day d. Each file contains orbital state vectors at fixed time steps of 10 seconds.
- **POE Orbit File**:
  - The position accuracy threshold is 3 cm radial 1-sigma RMS with a target of 2 cm.
  - The file is generated per day with a latency of 28 days after data acquisition.

  - The file coverage 26 hours (one complete day plus 1 hour before the start and after the end of the day – overlap of two hours between consecutive files – configurable) and contains orbital state vectors at time steps of 10 seconds intervals (configurable).

- **NRT Platform Data File**:
  - The accuracy threshold of roll and pitch axis biases is 0.05 degrees (3-sigma RMS).
  - The accuracy threshold of yaw axis biases is 0.5 degrees (3-sigma RMS).
  - The file is generated together with the NRT Restituted Orbit file.
  - The file coverage is equal to the input GNSS data.
- **Preliminary Platform Data File**:
  - The accuracy threshold of roll and pitch axis biases is 0.05 degrees (3-sigma RMS).
  - The accuracy threshold of yaw axis biases is 0.5 degrees (3-sigma RMS).
  - The file is generated together with the MOE Orbit file.
  - The file coverage is equal to the MOE Orbit file with which it is generated.
- **Precise Platform Data File**:
  - The accuracy threshold of roll and pitch axis biases is 0.05 degrees (3-sigma RMS).
  - The accuracy threshold of yaw axis biases is 0.5 degrees (3-sigma RMS).
  - The file is generated together with the POE Orbit file.
  - The file coverage is equal to the POE Orbit file with which it is generated.

Aside from the previous POD products, there are others such as POD products quality reports, including GNSS sensor performance monitoring information, GNSS USO report or anomaly reports. This second set of products do not have performance requirements as those mentioned above for the orbital and attitude products for the Sentinel-3 mission.

3. SENTINEL-3 PRODUCTS PERFORMANCE

This section describes the performance of each of the POD products generated for Sentinel-3 as compared to the POD requirements (position accuracy, coverage, timeliness, latency). The Cal/Val plan of the Sentinel-3 mission [AD.2] presents completely the calibration and validation tasks aimed at characterising the accuracy of the Sentinel-3 POD products. As part of the Cal/Val tasks, different reports are generated that justify the values presented in this document. Morevover, the Sentinel-3 POD products Quality Control Plan [AD.3] also provides information about metrics computed routinely related to the accuracy of the Sentinel-3 POD products.

The following table presents the requirements of the Sentinel-3 POD products:

Table 3-1: Requirements table for the Sentinel-3 POD products

Product	Latency	Requirement metric	Requirement value
NRT Restituted Orbit File (SR___ROE_AX)	NRT	Position accuracy in radial 1-sigma RMS	10 cm
MOE Orbit File (AUX_MOEORB)	STC	Position accuracy in radial 1-sigma RMS	4 cm
POE Orbit File (AUX_POEORB)	NTC	Position accuracy in radial 1-sigma RMS	3 cm
NRT Platform Data File (SR_2_NRPPAX)	NRT	Accuracy of roll, pitch and yaw axis biases	0.05 degrees for pitch and roll 0.5 degrees for yaw
Preliminary Platform Data File (AUX_PRLPTF)	STC	Accuracy of roll, pitch and yaw axis biases in 3-sigma RMS	0.05 degrees for pitch and roll 0.5 degrees for yaw
Precise Platform Data File (AUX_PRCPTF)	NTC	Accuracy of roll, pitch and yaw axis biases in 3-sigma RMS	0.05 degrees for pitch and roll 0.5 degrees for yaw

The tables of the following sub sections present the estimated accuracy of the POD products associated to a given processing baseline. A processing baseline is composed by a system version (software and configuration), and a set of input data. The description of the processing baselines in terms of models, changes with respect to other processing baselines, inputs and output coverage, etc., is provided in the POD product handbook [AD.4]. The source column of the tables indicates the centre generating the product, which are listed in Table 3-2.

Table 3-2: Description of orbit solutions

Name	Centre	POD SW
AIUB	Astronomical Institute University of Bern	Bernese
AING	Astronomical Institute University of Bern	Bernese (Non-gravitational)
CNES	Centre National d'Études Spatiales	ZOOM
COMB	ALL	ALL
CPOD	Copernicus POD Service – GMV	NAPEOS
DLR	Deutsche Zentrum für Luft- und Raumfahrt	GHOST
ESOC	European Space Operation Centre	NAPEOS
EUM	EUMETSAT	NAPEOS
EUMB	EUMETSAT	Bernese
GFZ	Geo Forschungs Zentrum	EPOS-OC
GRG	Groupe de Recherche de Géodésie Spatiale	GINS/DYNAMO
JPL	Jet Propulsion Laboratory	GIPSY-OASIS
TUDF	Technische Universiteit Delft	GHOST
TUDG	Technische Universiteit Delft	GIPSY-OASIS
TUM	Technische Universität München	Bernese

The following tables and plots show different metrics:

1. Average and standard deviation of the comparisons over the time period reported.
2. The 1-sigma (68%), 2-sigma (95%) and 3-sigma (99.7%) of the NRT and STC comparisons over the time period reported.

In order not to harm the statistics of the comparisons due to degraded products from manoeuvres or gaps of data, a filetering criterion has been included. Thus, comparisons above two times the accuracy requirement of the products have been filtered-out.

3.1. 2016

Table 3-3: Estimated accuracy of CPOD products for March – May 2016 [RD.1]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
SPOD_SYSTEM_v1.0.0 SPOD_SYSTEM_v1.0.1 SPOD_SYSTEM_v1.0.2 SPOD_SYSTEM_v1.0.3 SPOD_SYSTEM_v1.0.4 SPOD_SYSTEM_v1.0.5 SPOD_SYSTEM_v1.0.6 SPOD_SYSTEM_v1.0.7 SPOD_SYSTEM_v1.0.8	STC [radial RMS]	CPOD vs. ESOC	2.07	N/A
		CPOD vs. CNES MDO	1.79	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.11 ± 0.11	N/A
		CPOD vs. CNES	0.56 ± 0.15	N/A
		CPOD vs. DLR	0.80 ± 0.15	N/A
		CPOD vs. ESOC	0.67 ± 0.65	N/A
		CPOD vs. EUM	1.36 ± 0.21	N/A
		CPOD vs. TUDF	0.80 ± 0.30	N/A
		CPOD vs. TUM	1.59 ± 0.31	N/A
		CPOD vs. COMB	**0.62 ± 0.09**	N/A
		CNES POE vs. COMB	**0.62 ± 0.08**	N/A

Table 3-4: Estimated accuracy of CPOD products for July – September 2016 [RD.2]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_15 S3PODIPF_v02_16 S3PODIPF_v02_17	NRT [radial RMS]	MAR vs. CNES MGN	1.23 ± 0.88 (av) 1.34 (1-sigma) 2.23 (2-sigma) 8.20 (3-sigma)	N/A
		LND vs. CNES MGN	1.33 ± 0.92 (av) 1.45 (1-sigma) 2.42 (2-sigma) 6.44 (3-sigma)	N/A
SPOD_SYSTEM_v1.0.8 SPOD_SYSTEM_v1.0.9 SPOD_SYSTEM_v1.0.10	STC [radial RMS]	CPOD vs. CNES MDO	0.95 ± 0.21 (av) 1.02 (1-sigma) 1.30 (2-sigma) 1.61 (3-sigma)	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.08 ± 0.08	N/A
		CPOD vs. CNES	0.53 ± 0.09	N/A
		CPOD vs. DLR	1.05 ± 0.08	N/A
		CPOD vs. ESOC	0.69 ± 0.12	N/A
		CPOD vs. TUDF	0.92 ± 0.08	N/A
		CPOD vs. TUM	1.54 ± 0.18	N/A
		CPOD vs. COMB	**0.73 ± 0.09**	N/A
		CNES POE vs. COMB	**0.65 ± 0.09**	N/A

Table 3-5: Estimated accuracy of CPOD products for October 2016 – January 2017 [RD.3]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_17 S3PODIPF_v02_18	NRT [radial RMS]	MAR vs. CNES MGN	1.33 ± 0.84 (av) 1.50 (1-sigma) 2.48 (2-sigma) 5.42 (3-sigma)	N/A
		LND vs. CNES MGN	1.31 ± 0.76 (av) 1.48 (1-sigma) 2.49 (2-sigma) 5.42 (3-sigma)	N/A
SPOD_SYSTEM_v1.0.10 SPOD_SYSTEM_v1.1.0 SPOD_SYSTEM_v1.1.1 SPOD_SYSTEM_v1.2.0 SPOD_SYSTEM_v1.2.1	STC [radial RMS]	CPOD vs. CNES MDO	1.02 ± 0.23 (av) 1.07 (1-sigma) 1.50 (2-sigma) 1.79 (3-sigma)	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.12 ± 0.11	N/A
		CPOD vs. CNES	0.57 ± 0.10	N/A
		CPOD vs. DLR	0.99 ± 0.10	N/A
		CPOD vs. ESOC	0.58 ± 0.11	N/A
		CPOD vs. EUM	0.53 ± 0.12	N/A
		CPOD vs. TUDF	0.93 ± 0.10	N/A
		CPOD vs. TUM	1.73 ± 0.19	N/A
		CPOD vs. COMB	**0.56 ± 0.08**	N/A
		CNES POE vs. COMB	**0.52 ± 0.06**	N/A

3.2. 2017

Table 3-6: Estimated accuracy of CPOD products for February – May 2017 [RD.4]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_18	NRT [radial RMS]	MAR vs. CNES MGN	1.16 ± 1.01 (av) 1.25 (1-sigma) 2.22 (2-sigma) 10.21 (3-sigma)	N/A
		LND vs. CNES MGN	1.13 ± 1.06 (av) 1.22 (1-sigma) 2.09 (2-sigma) 11.73 (3-sigma)	N/A
SPOD_SYSTEM_v1.3.0 SPOD_SYSTEM_v1.3.1 SPOD_SYSTEM_v1.3.2	STC [radial RMS]	CPOD vs. CNES MDO	0.87 ± 0.16 (av) 0.93 (1-sigma) 1.13 (2-sigma) 1.25 (3-sigma)	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.25 ± 0.08	N/A
		CPOD vs. CNES	0.53 ± 0.08	N/A
		CPOD vs. DLR	1.21 ± 0.09	N/A
		CPOD vs. ESOC	0.54 ± 0.11	N/A
		CPOD vs. EUM	0.65 ± 0.10	N/A
		CPOD vs. TUDF	0.98 ± 0.09	N/A
		CPOD vs. TUDG	0.97 ± 0.08	N/A
		CPOD vs. TUM	0.84 ± 0.14	N/A

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
		CPOD vs. COMB	**0.64 ± 0.08**	N/A
		CNES POE vs. COMB	**0.63 ± 0.09**	N/A

Table 3-7: Estimated accuracy of CPOD products for June – September 2017 [RD.5]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_18	NRT [radial RMS]	MAR vs. CNES MGN	1.20 ± 1.07 (av) 1.27 (1-sigma) 2.31 (2-sigma) 10.54 (3-sigma)	N/A
		LND vs. CNES MGN	1.25 ± 1.25 (av) 1.28 (1-sigma) 2.37 (2-sigma) 12.45 (3-sigma)	N/A
SPOD_SYSTEM_v1.3.3 SPOD_SYSTEM_v1.3.4 SPOD_SYSTEM_v1.3.5 SPOD_SYSTEM_v1.3.6	STC [radial RMS]	CPOD vs. CNES MDO	0.91 ± 0.15 (av) 0.98 (1-sigma) 1.16 (2-sigma) 1.33 (3-sigma)	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.26 ± 0.39	N/A
		CPOD vs. CNES	0.51 ± 0.11	N/A
		CPOD vs. DLR	0.91 ± 0.10	N/A
		CPOD vs. ESOC	0.52 ± 0.11	N/A
		CPOD vs. EUM	0.61 ± 0.10	N/A
		CPOD vs. GRG	0.68 ± 0.14	N/A
		CPOD vs. TUDF	1.00 ± 0.09	N/A
		CPOD vs. TUDG	0.91 ± 0.07	N/A
		CPOD vs. TUM	0.98 ± 0.13	N/A
		CPOD vs. COMB	**0.59 ± 0.08**	N/A
		CNES POE vs. COMB	**0.60 ± 0.08**	N/A

Table 3-8: Estimated accuracy of CPOD products for October 2017 – January 2018 [RD.6]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_19 S3PODIPF_v02_20	NRT [radial RMS]	MAR vs. CNES MGN	0.97 ± 0.46 (av) 1.11 (1-sigma) 1.79 (2-sigma) 2.72 (3-sigma)	N/A
		LND vs. CNES MGN	0.97 ± 0.46 (av) 1.12 (1-sigma) 1.81 (2-sigma) 2.70 (3-sigma)	N/A
SPOD_SYSTEM_v1.3.7 SPOD_SYSTEM_v1.3.8 SPOD_SYSTEM_v1.3.9 SPOD_SYSTEM_v1.4.0	STC [radial RMS]	CPOD vs. CNES MDO	1.03 ± 0.18 (av) 1.12 (1-sigma) 1.33 (2-sigma) 1.62 (3-sigma)	N/A

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
	NTC [radial RMS]	CPOD vs. AIUB	1.26 ± 0.10	N/A
		CPOD vs. AING	0.74 ± 0.08	N/A
		CPOD vs. CNES	0.71 ± 0.12	N/A
		CPOD vs. DLR	1.09 ± 0.09	N/A
		CPOD vs. ESOC	0.51 ± 0.12	N/A
		CPOD vs. EUM	0.64 ± 0.33	N/A
		CPOD vs. GRG	0.71 ± 0.12	N/A
		CPOD vs. TUDF	1.08 ± 0.09	N/A
		CPOD vs. TUDG	0.96 ± 0.08	N/A
		CPOD vs. TUM	0.90 ± 0.13	N/A
		CPOD vs. COMB	**0.60 ± 0.11**	N/A
		CNES POE vs. COMB	**0.69 ± 0.13**	N/A

3.3. 2018

Table 3-9: Estimated accuracy of CPOD products for February – May 2018 [RD.7]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_20 S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MGN	1.24 ± 1.06 (av) 1.34 (1-sigma) 2.34 (2-sigma) 10.35 (3-sigma)	N/A
		LND vs. CNES MGN	1.25 ± 1.06 (av) 1.35 (1-sigma) 2.37 (2-sigma) 10.35 (3-sigma)	N/A
SPOD_SYSTEM_v1.4.1 SPOD_SYSTEM_v1.4.2 SPOD_SYSTEM_v1.4.3	STC [radial RMS]	CPOD vs. CNES MDO	1.06 ± 0.46 (av) 1.11 (1-sigma) 1.39 (2-sigma) 5.63 (3-sigma)	N/A
	NTC [radial RMS]	CPOD vs. AIUB	1.27 ± 0.07	N/A
		CPOD vs. AING	0.78 ± 0.09	N/A
		CPOD vs. CNES	0.65 ± 0.09	N/A
		CPOD vs. DLR	0.85 ± 0.08	N/A
		CPOD vs. ESOC	0.70 ± 0.09	N/A
		CPOD vs. EUM	0.78 ± 0.11	N/A
		CPOD vs. GRG	0.66 ± 0.14	N/A
		CPOD vs. TUDG	1.06 ± 0.06	N/A
		CPOD vs. TUM	0.94 ± 0.10	N/A
		CPOD vs. COMB	**0.60 ± 0.08**	**N/A**
		CNES POE vs. COMB	**0.59 ± 0.08**	**N/A**

Table 3-10: Estimated accuracy of CPOD products for June – September 2018 [RD.8]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MGN	1.28 ± 0.87 (av) 1.38 (1-sigma) 2.60 (2-sigma) 7.70 (3-sigma)	1.08 ± 0.60 (av) 1.24 (1-sigma) 2.10 (2-sigma) 3.71 (3-sigma)
		LND vs. CNES MGN	1.32 ± 0.98 (av) 1.41 (1-sigma) 2.78 (2-sigma) 8.38 (3-sigma)	1.05 ± 0.57 (av) 1.20 (1-sigma) 2.01 (2-sigma) 3.69 (3-sigma)
SPOD_SYSTEM_v1.5.0	STC [radial RMS]	CPOD vs. CNES MDO	0.74 ± 0.13 (av) 0.75 (1-sigma) 0.99 (2-sigma) 1.49 (3-sigma)	0.87 ± 0.20 (av) 0.92 (1-sigma) 1.18 (2-sigma) 1.85 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.73 ± 0.08	N/A
		CPOD vs. AIUB	1.27 ± 0.10	0.95 ± 0.08
		CPOD vs. CNES	0.74 ± 0.09	0.67 ± 0.10
		CPOD vs. DLR	0.80 ± 0.07	0.70 ± 0.06
		CPOD vs. ESOC	0.55 ± 0.07	0.67 ± 0.09
		CPOD vs. EUM	0.68 ± 0.18	0.69 ± 0.08
		CPOD vs. GRG	0.68 ± 0.08	0.61 ± 0.14
		CPOD vs. TUDG	1.26 ± 0.70	0.53 ± 0.07
		CPOD vs. TUM	0.92 ± 0.08	0.64 ± 0.07
		CPOD vs. COMB	**0.57 ± 0.06**	**0.44 ± 0.06**
		CNES POE vs. COMB	**0.58 ± 0.08**	**0.49 ± 0.07**

Table 3-11: Estimated accuracy of CPOD products for October 2018 – January 2019 [RD.9]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MGN	1.08 ± 0.51 (av) 1.24 (1-sigma) 2.08 (2-sigma) 3.01 (3-sigma)	1.14 ± 0.82 (av) 1.25 (1-sigma) 2.19 (2-sigma) 7.15 (3-sigma)
		LND vs. CNES MGN	1.10 ± 0.53 (av) 1.25 (1-sigma) 2.11 (2-sigma) 3.20 (3-sigma)	1.15 ± 0.85 (av) 1.25 (1-sigma) 2.23 (2-sigma) 7.15 (3-sigma)
SPOD_SYSTEM_v1.5.1 SPOD_SYSTEM_v1.5.2 SPOD_SYSTEM_v1.5.3	STC [radial RMS]	CPOD vs. CNES MDO	0.74 ± 0.17 (av) 0.76 (1-sigma) 1.04 (2-sigma) 1.46 (3-sigma)	0.85 ± 0.73 (av) 0.82 (1-sigma) 1.23 (2-sigma) 7.52 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.79 ± 0.10	0.70 ± 0.08
		CPOD vs. AIUB	1.33 ± 0.10	1.03 ± 0.09
		CPOD vs. CNES	0.68 ± 0.09	0.62 ± 0.10
		CPOD vs. DLR	0.85 ± 0.10	0.69 ± 0.08
		CPOD vs. ESOC	0.58 ± 0.08	0.51 ± 0.07
		CPOD vs. EUM	0.69 ± 0.09	0.70 ± 0.10
		CPOD vs. GRG	0.79 ± 0.14	0.76 ± 0.15
		CPOD vs. TUDG	1.08 ± 0.06	0.59 ± 0.08

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
		CPOD vs. TUM	0.99 ± 0.09	0.72 ± 0.09
		CPOD vs. COMB	**0.59 ± 0.07**	**0.46 ± 0.07**
		CNES POE vs. COMB	**0.45 ± 0.09**	**0.45 ± 0.15**

3.4. 2019

Table 3-12: Estimated accuracy of CPOD products for February – May 2019 [RD.10]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MGN	1.14 ± 0.62 (av) 1.28 (1-sigma) 2.37 (2-sigma) 3.53 (3-sigma)	1.25 ± 0.68 (av) 1.39 (1-sigma) 2.46 (2-sigma) 4.35 (3-sigma)
		LND vs. CNES MGN	1.19 ± 0.80 (av) 1.34 (1-sigma) 2.41 (2-sigma) 3.59 (3-sigma)	1.29 ± 0.69 (av) 1.45 (1-sigma) 2.66 (2-sigma) 4.35 (3-sigma)
SPOD_SYSTEM_v1.5.4	STC [radial RMS]	CPOD vs. CNES MDO	0.69 ± 0.19 (av) 0.71 (1-sigma) 1.10 (2-sigma) 1.54 (3-sigma)	0.75 ± 0.20 (av) 0.77 (1-sigma) 1.07 (2-sigma) 1.67 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.83 ± 0.07	0.72 ± 0.06
		CPOD vs. AIUB	1.15 ± 0.07	0.92 ± 0.07
		CPOD vs. CNES	0.76 ± 0.08	0.66 ± 0.07
		CPOD vs. DLR	0.90 ± 0.07	0.77 ± 0.07
		CPOD vs. ESOC	0.67 ± 0.09	0.61 ± 0.08
		CPOD vs. EUMB	1.34 ± 0.11	1.04 ± 0.08
		CPOD vs. EUM	0.83 ± 0.10	0.84 ± 0.11
		CPOD vs. GRG	0.87 ± 0.13	0.79 ± 0.13
		CPOD vs. TUDG	1.15 ± 0.06	0.74 ± 0.09
		CPOD vs. TUM	1.12 ± 0.12	0.86 ± 0.08
		CPOD vs. COMB	**0.72 ± 0.06**	**0.61 ± 0.07**
		CNES POE vs. COMB	**0.39 ± 0.04**	**0.30 ± 0.05**

Table 3-13: Estimated accuracy of CPOD products for June – September 2019 [RD.11]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MDO	1.39 ± 0.81 (av) 1.52 (1-sigma) 2.72 (2-sigma) 6.06 (3-sigma)	1.38 ± 0.87 (av) 1.51 (1-sigma) 2.78 (2-sigma) 6.75 (3-sigma)
		LND vs. CNES MDO	1.45 ± 0.87 (av) 1.59 (1-sigma) 2.95 (2-sigma) 6.33 (3-sigma)	1.44 ± 1.09 (av) 1.56 (1-sigma) 2.93 (2-sigma) 9.24 (3-sigma)

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
SPOD_SYSTEM_v1.5.4	STC [radial RMS]	CPOD vs. CNES MDO	0.80 ± 0.15 (av) 0.84 (1-sigma) 1.06 (2-sigma) 1.66 (3-sigma)	0.82 ± 0.20 (av) 0.86 (1-sigma) 1.07 (2-sigma) 2.31 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.77 ± 0.08	0.63 ± 0.07
		CPOD vs. AIUB	1.05 ± 0.09	0.79 ± 0.08
		CPOD vs. CNES	0.80 ± 0.07	0.72 ± 0.07
		CPOD vs. DLR	0.85 ± 0.09	0.70 ± 0.08
		CPOD vs. ESOC	0.67 ± 0.09	0.61 ± 0.08
		CPOD vs. EUMB	1.39 ± 0.10	0.99 ± 0.10
		CPOD vs. GRG	0.91 ± 0.12	0.82 ± 0.12
		CPOD vs. TUDG	1.15 ± 0.11	0.68 ± 0.12
		CPOD vs. TUM	1.13 ± 0.11	0.83 ± 0.08
		CPOD vs. COMB	**0.67 ± 0.07**	**0.53 ± 0.07**
		CNES POE vs. COMB	**0.56 ± 0.06**	**0.45 ± 0.08**

Table 3-14: Estimated accuracy of CPOD products for October 2019 – January 2020 [RD.12]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MDO	0.95 ± 0.49 (av) 1.07 (1-sigma) 1.71 (2-sigma) 2.77 (3-sigma)	0.90 ± 0.50 (av) 1.02 (1-sigma) 1.63 (2-sigma) 2.67 (3-sigma)
		LND vs. CNES MDO	0.99 ± 0.56 (av) 1.11 (1-sigma) 1.78 (2-sigma) 3.74 (3-sigma)	0.93 ± 0.47 (av) 1.05 (1-sigma) 1.70 (2-sigma) 3.27 (3-sigma)
SPOD_SYSTEM_v1.5.4 SPOD_SYSTEM_v1.5.5	STC [radial RMS]	CPOD vs. CNES MDO	0.68 ± 0.10 (av) 0.71 (1-sigma) 0.87 (2-sigma) 1.00 (3-sigma)	0.60 ± 0.12 (av) 0.63 (1-sigma) 0.82 (2-sigma) 1.04 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.78 ± 0.09	0.59 ± 0.10
		CPOD vs. AIUB	1.08 ± 0.10	0.81 ± 0.11
		CPOD vs. CNES	0.70 ± 0.09	0.57 ± 0.10
		CPOD vs. DLR	0.86 ± 0.10	0.69 ± 0.10
		CPOD vs. ESOC	0.65 ± 0.08	0.54 ± 0.07
		CPOD vs. EUMB	1.44 ± 0.12	0.91 ± 0.11
		CPOD vs. GFZ	0.92 ± 0.11	0.96 ± 0.09
		CPOD vs. GRG	1.03 ± 0.14	0.94 ± 0.12
		CPOD vs. JPL	0.77 ± 0.09	0.54 ± 0.09
		CPOD vs. TUDG	1.17 ± 0.09	0.71 ± 0.13
		CPOD vs. TUM	1.03 ± 0.09	0.76 ± 0.10
		CPOD vs. COMB	**0.65 ± 0.08**	**0.48 ± 0.08**
		CNES POE vs. COMB	**0.38 ± 0.05**	**0.35 ± 0.06**

3.5. 2020

Table 3-15: Estimated accuracy of CPOD products for February – May 2020 [RD.13]

Processing baseline identifier [AD.4]	Product type	Source	S-3A Mean ± stdev (cm)	S-3B Mean ± stdev (cm)
S3PODIPF_v02_21	NRT [radial RMS]	MAR vs. CNES MDO	1.04 ± 0.50 (av) 1.18 (1-sigma) 1.98 (2-sigma) 2.96 (3-sigma)	1.05 ± 0.56 (av) 1.16 (1-sigma) 2.03 (2-sigma) 3.60 (3-sigma)
		LND vs. CNES MDO	1.05 ± 0.52 (av) 1.19 (1-sigma) 1.99 (2-sigma) 3.08 (3-sigma)	1.04 ± 0.53 (av) 1.16 (1-sigma) 2.01 (2-sigma) 3.52 (3-sigma)
SPOD_SYSTEM_v1.5.4 SPOD_SYSTEM_v1.5.5	STC [radial RMS]	CPOD vs. CNES MDO	0.67 ± 0.12 (av) 0.71 (1-sigma) 0.86 (2-sigma) 1.02 (3-sigma)	0.71 ± 0.11 (av) 0.76 (1-sigma) 0.88 (2-sigma) 1.00 (3-sigma)
	NTC [radial RMS]	CPOD vs. AING	0.64 ± 0.13	0.60 ± 0.11
		CPOD vs. AIUB	1.01 ± 0.08	0.84 ± 0.08
		CPOD vs. CNES	0.58 ± 0.13	0.55 ± 0.11
		CPOD vs. DLR	0.76 ± 0.13	0.68 ± 0.11
		CPOD vs. ESOC	0.61 ± 0.07	0.56 ± 0.07
		CPOD vs. EUMB	1.18 ± 0.11	0.92 ± 0.10
		CPOD vs. GFZ	0.66 ± 0.09	0.67 ± 0.09
		CPOD vs. GRG	0.86 ± 0.18	0.86 ± 0.16
		CPOD vs. JPL	0.61 ± 0.13	0.51 ± 0.11
		CPOD vs. TUDG	0.67 ± 0.16	0.62 ± 0.12
		CPOD vs. TUM	0.83 ± 0.12	0.71 ± 0.10
		CPOD vs. COMB	**0.52 ± 0.13**	**0.48 ± 0.11**
		CNES POE vs. COMB	**0.29 ± 0.04**	**0.27 ± 0.04**

3.6. OVERALL

The following figures show the averages and 1-sigma and 3-sigma reported in the previous tables.

3.6.1. NRT MAR

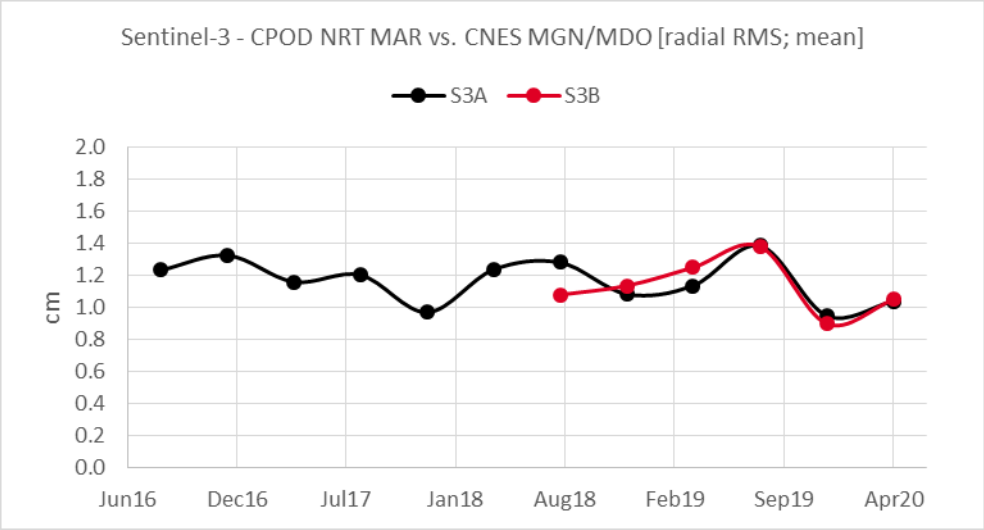

Figure 3-1: Sentinel-3 CPOD NRT MAR vs. CNES MGN/MDO [radial RMS; mean] (cm)

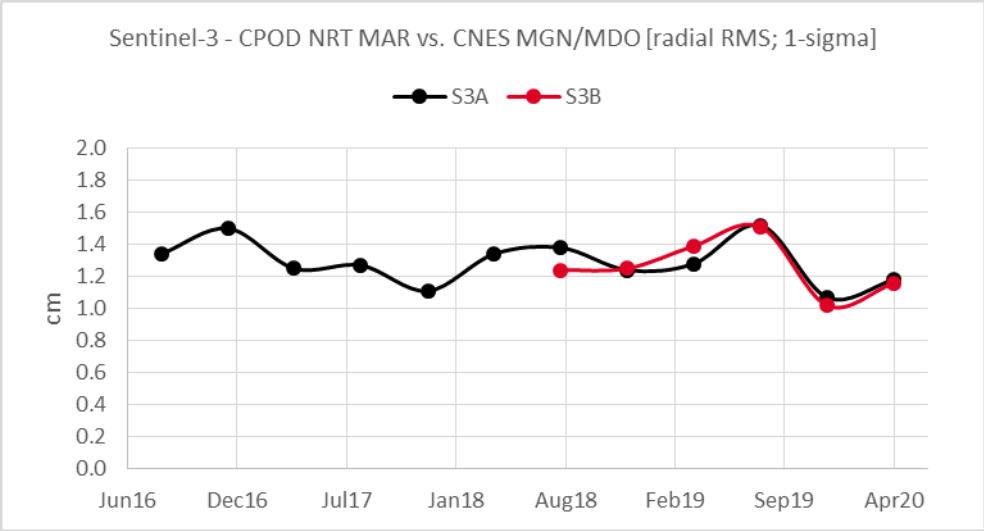

Figure 3-2: Sentinel-3 CPOD NRT MAR vs. CNES MGN/MDO [radial RMS; 1-sigma] (cm)

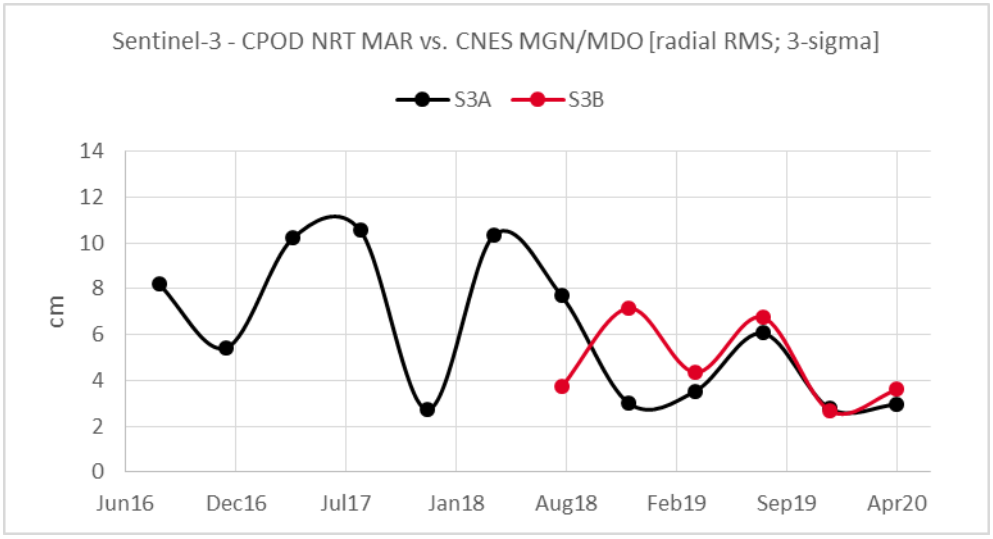

Figure 3-3: Sentinel-3 CPOD NRT MAR vs. CNES MGN/MDO [radial RMS; 3-sigma] (cm)

3.6.2. NRT LND

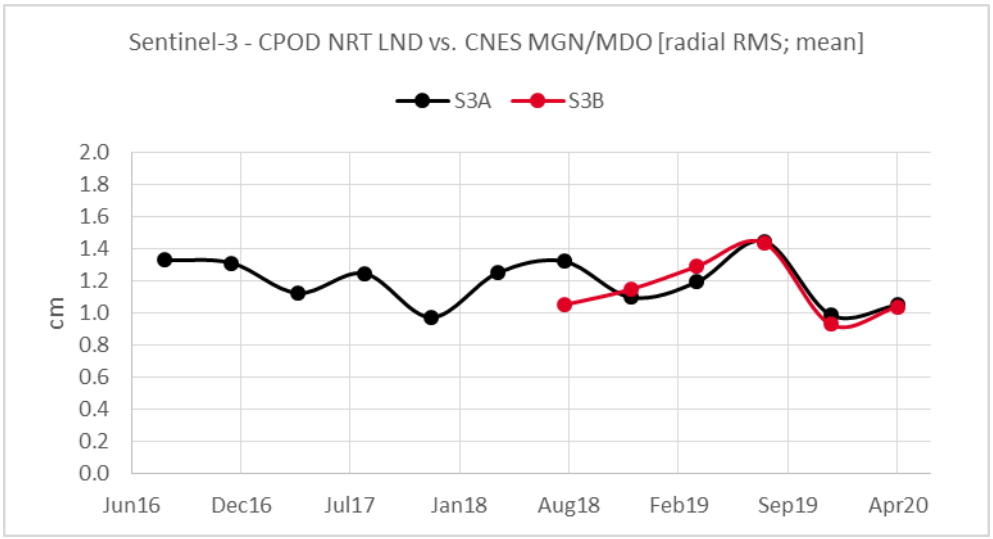

Figure 3-4: Sentinel-3 CPOD NRT LND vs. CNES MGN/MDO [radial RMS; mean] (cm)

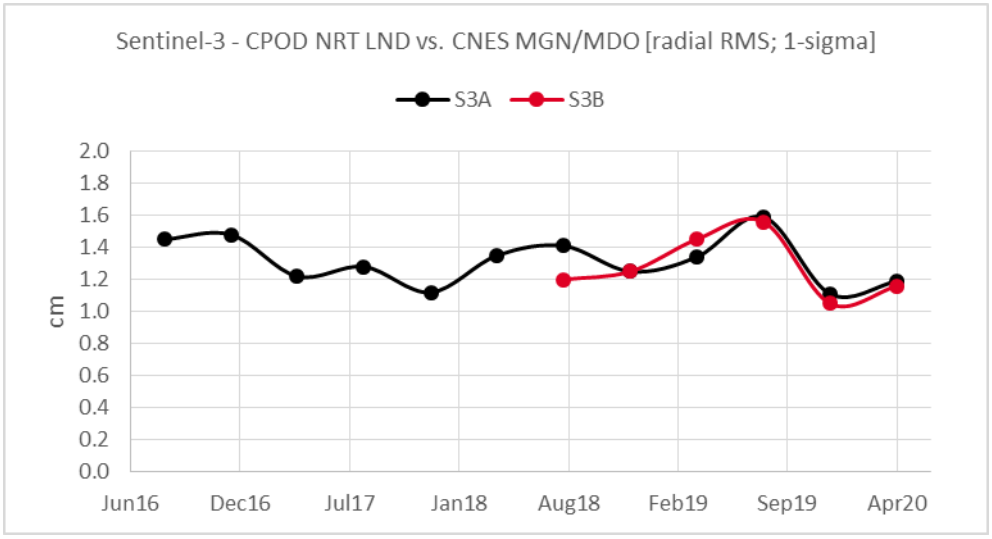

Figure 3-5: Sentinel-3 CPOD NRT LND vs. CNES MGN/MDO [radial RMS; 1-sigma] (cm)

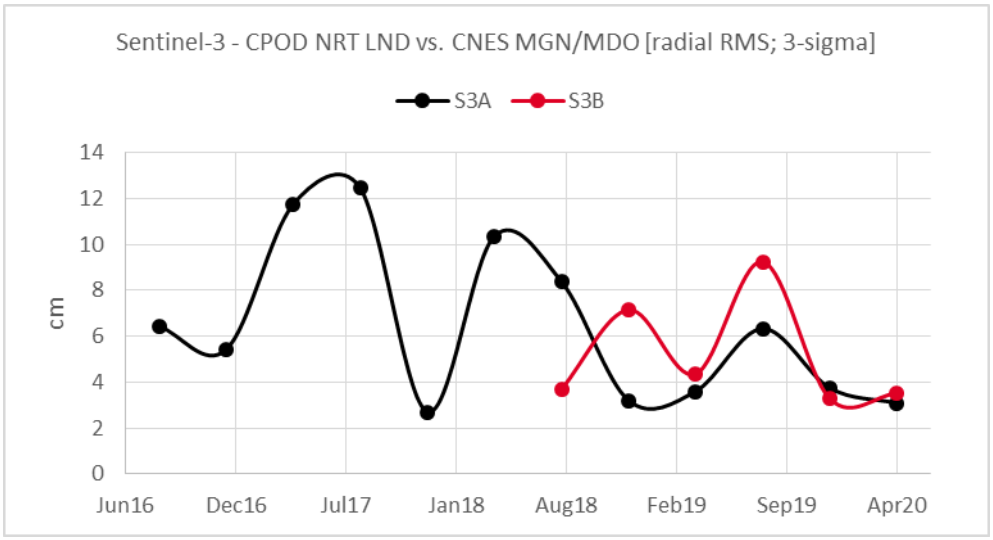

Figure 3-6: Sentinel-3 CPOD NRT LND vs. CNES MGN/MDO [radial RMS; 3-sigma] (cm)

3.6.3. STC

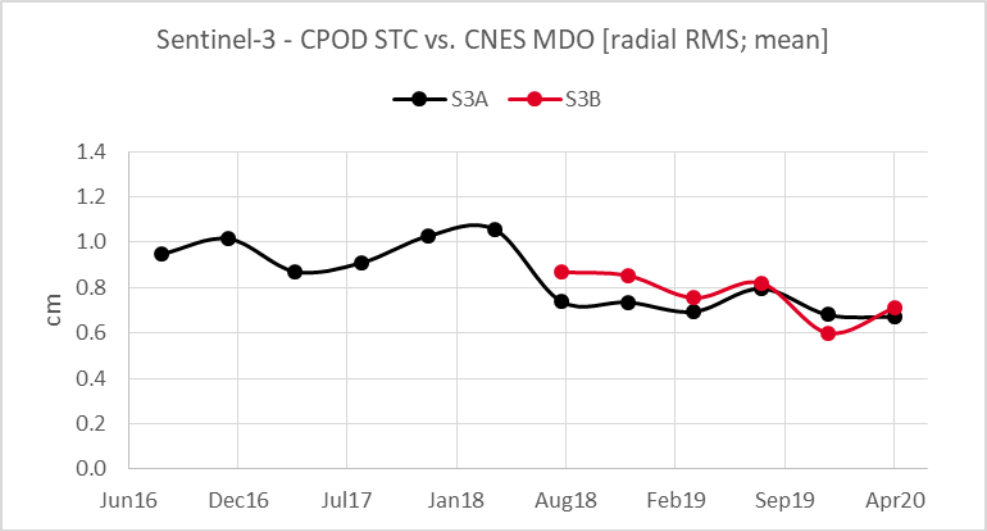

Figure 3-7: Sentinel-3 CPOD STC vs. CNES MDO [radial RMS; mean] (cm)

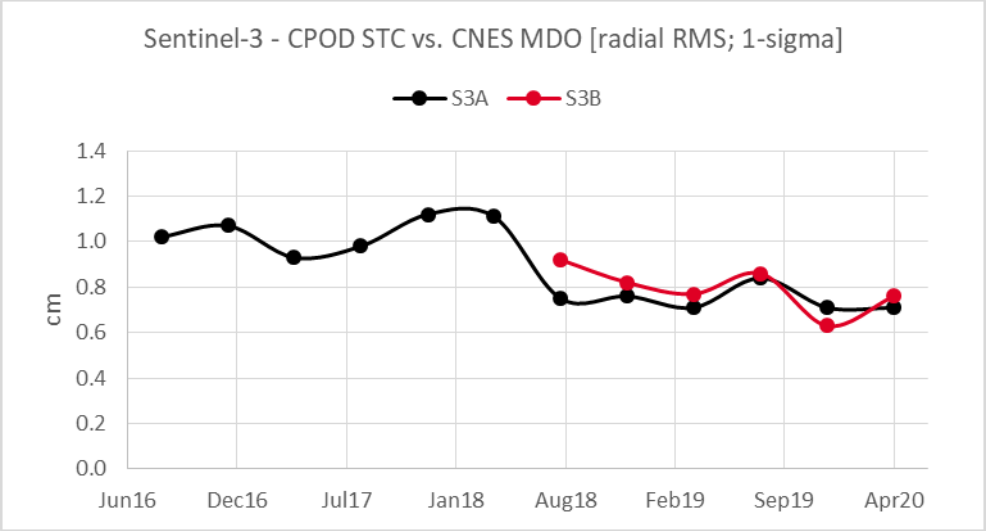

Figure 3-8: Sentinel-3 CPOD STC vs. CNES MDO [radial RMS; 1-sigma] (cm)

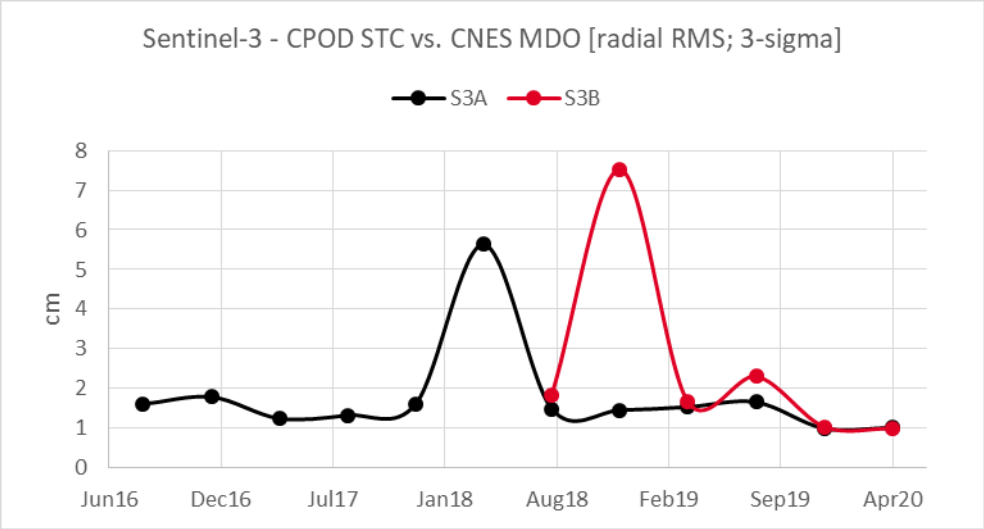

Figure 3-9: Sentinel-3 CPOD STC vs. CNES MDO [radial RMS; 3-sigma] (cm)

3.6.4. NTC

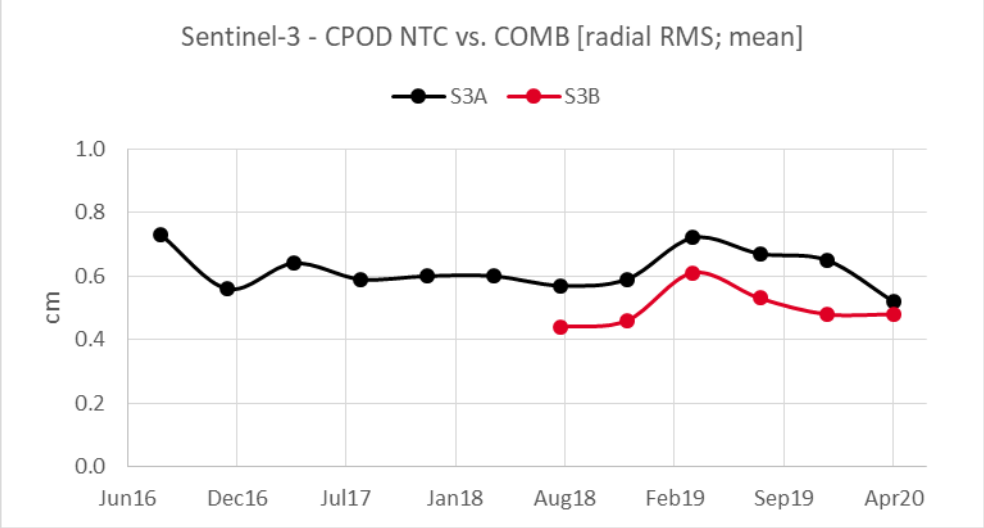

Figure 3-10: Sentinel-3 CPOD NTC vs. COMB [radial RMS; mean] (cm)

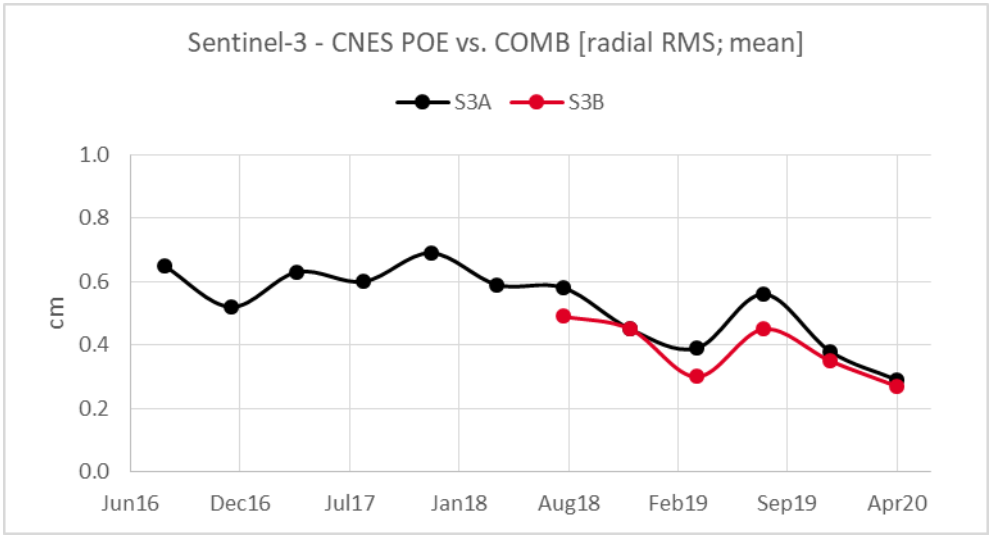

Figure 3-11: Sentinel-3 CNES POE vs. COMB [radial RMS; mean] (cm)

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